Observations on forest restoration in Jilin, China

A. Mosseler[1], B. Pendrel[1], W. Wang[1], NIU Yan-zhang[2], Y.S. Park[1], GAO Chang-qi[3], SONG Li-wen[3]

[1]. *Canadian Forest Service: Atlantic Forestry Centre, ,P.O. Box 4000, Fredericton, N.B, E3B 5P7 Canada;*

[2]. *Jilin Province Foreign Expert Bureau, Changchun, 130051, P. R. China;*

[3]. *Jilin Provincial Academy of Forestry Sciences, Changchun 130033, P. R. China*

Abstract: This paper reviews various forestry practices in Jilin Province, China. The authors emphasize the rich natural diversity of Jilin and the need to focus research efforts on understanding the potential of native species to meet the needs of land-management agencies involved in forest resource exploitation and ecological restoration. The native species of China hold great potential, and deserve more research attention, for meeting these needs. The introduction and testing of exotic species should be done only under rigorous scientific testing and after comparison with native species prior to operational introduction into forestry in order to avoid unwanted ecological consequences, including potential problems with alien invasives and pest introductions. The authors also emphasize the need to maintain viable (e.g., genetically diverse and reproductively fit) natural populations of native species in order to protect China's valuable natural diversity and maintain the potential of native species to function as future seed sources for local forest and ecological restoration activities.

Keywords: Biodiversity conservation; Exotic species; Forest restoration; Native trees and forest types; Population viability

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Introduction

Annually since 1998, scientists from the Canadian Forest Service and Jilin Academy of Forestry Sciences have investigated forest management and restoration activities in Jilin, China. They have consulted with the local scientists about the various options available. Sites included the grasslands of western Jilin, Changbai Mountains, and areas of mixed agriculture and forestry. These investigations exposed Canadian scientists to forest and landscape conditions in China and promoted discussion of issues, problems, and opportunities in forest restoration on degraded sites (Wang 2001). There are many similarities between northeastern North America and northeastern China, in climate, physiography, forest ecology, forest structure and composition, and the impacts of past forest exploitation. This paper reviews our observations, thoughts, and discussions.

From the Canadian perspective, we were impressed with local forestry expertise and activities, particularly in the area of forest restoration under very difficult circumstances. We hope our observations will encourage and support the important work and efforts of local experts. Major changes have recently been announced in the forest policies of both China and Jilin. These policy changes recognize the ecological value of forests as the primary aim of forest management in China, and provide a strong foundation for restoration of native species and forest types. Although these policies allow for the potential introduction and testing of exotic species and the use of advanced biotechnology to address especially challenging environmental conditions, we remain convinced that the major advances in forest restoration will be based on the proper exploitation of well-adapted native species.

Therefore, a premise of this paper is that ecological restoration should focus on the use of native tree species and forest types wherever possible because native species are normally the best adapted to growth and survival under local conditions. There are ecological risks associated with the introduction of non-native genetic material. Such introductions should be based on a careful ecological rationale and justified by special circumstances. This paper has been organized into 10 sections, each presenting a brief discussion of one or two concepts related to our observations. Each section concludes with a specific recommendation regarding forest management and restoration.

Observations on forests and restoration activities

Mountain Forests

In the Changbai Mountains of eastern Jilin, forests on the slopes and mountainsides have been cleared for the purposes of agriculture. This has led to soil depletion, drying, erosion, and eventual abandonment. This process reduces soil productivity and water quality, as streams experience increased siltation. Re-establishing forests on these eroded upper slopes becomes difficult when soils have been depleted to the extent that survival of the more desirable species, sought after for reforestation, are jeopardized by harsh, droughty conditions. Under such conditions, one of the best approaches to reforestation is establishment of mixed-species forest cover, including native larch species (e.g., *Larix olgensis* and *L. leptolepis*), mixed with native pines (e.g., *Pinus koraiensis* and *P. tabulaeformis*), spruces (e.g., *Picea koraiensis* and *P. jezoensis*) or firs (e.g., *Abies holophylla* and *A. nephrolepis*). When evergreen conifers, such as pines and spruces, are established without larch species or some other deciduous species to act as a nurse crop, conifer needles become vulnerable to wind damage caused by snow or sand abrasion. Abrasion removes the protective waxes on needle surfaces, resulting in drying of tissues. Larch or deciduous angiosperms (e.g., *Populus* spp., *Betula costata*, *Ulmus pumila*, or *Quercus mongolica*) not only serve as a protective cover, but the annual input of leaf litter from poplars and birches, can enhance soil fertility by promoting nutrient cycling.

In the coastal barren lands of northeastern Canada, where European settlers removed the original forest cover during the

Biography: A. Mosseler, Male, Research Scientist in Canadian Forest Service: Atlantic Forestry Centre, ,P.O. Box 4000, Fredericton, N.B, E3B 5P7 Canada. E-mail: amossele@nrcan.gc.ca

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colonization phase of Canadian history, Canada has experienced similar problems establishing conifer forests. Mixed-tree species plantings have been more likely to survive and have the added benefit of enhancing biological diversity by providing more varied and complex habitats for wildlife. In the Changbai Mountains, we observed successful examples of larch species mixtures with pines and spruces creating attractive plantations that might eventually mimic natural forest types. We recommend that artificial forest regeneration or restoration activities be based on this mixed species model of native species wherever wind-driven sand and snow create problems for evergreen conifers.

Much of the Changbai Mountains is fortunate enough to have almost continuous forest cover, including coveted natural reserve areas. Outside of the reserves, most forest is secondary growth, following many decades of continuous harvesting. Some of these areas experienced severe degradation during the 20th century. In second-growth areas, many of the desirable species, especially the pines, spruces, and firs, have been removed, leaving only oaks and poplars. The loss of these native conifers also represents a loss of commercial value. Restoration of native conifers would provide a more ecologically resilient and valuable forest. A Canadian approach, which may succeed in the Changbai Mountains, is to plan for a variety of reforestation styles from (1) intensive forestry based on fast-growing species, (2) the ecologically sustainable exploitation of areas of natural forest, and (3) the preservation of large tracts such as the Changbai Mountains Nature Reserve. This three-tiered approach implies the need for coordinated landscape planning across large areas, involving more than one local forestry bureau. This opens possibilities for enhanced classic tree improvement programs for both native and exotic species.

Agro-forestry Systems

Landscapes containing remnants of second-growth natural forest in areas largely dedicated to agriculture dominate central areas of Jilin. Given their good fertility, these could be choice sites for afforestation to restore forest cover for ecological benefits and commercial wood production. Reforestation with mixed native species, as described above, is the most suitable approach when a variety of values are desired from the forest and the potential for damage from insect and disease pests must be minimized. Exotic species could be considered in this region for their potential commercial benefits, as well as restoration of forest habitat. However, we recommend establishment of a research and testing program aimed at comparing native and exotic species to confirm that real advantages exist with exotics, whenever their introduction is considered. Plantation forestry should concentrate on the use of improved seed, yet we recognize that the lack of availability of this material may require establishment of tree improvement programs based on seed orchard development.

Grassland Desertification

The western part of Jilin has a semi-arid environment where agricultural activities have led to soil salination, increased alkalinity, and erosion by wind and water. Reversal of severe site degradation in such areas is problematic and may require many decades of restoration, research, and policies to eliminate contributing factors such as over-grazing. We do not attempt to describe all the possibilities here, but we highlight a few possible directions. Jilin Academy of Forest Sciences (Wang 2001) is testing exotic woody species, such as silverberry (*Eleagnus commutata*), a native North American species, in the grasslands of western Jilin for its salt tolerance and ability to establish itself on salinated soils. This approach is promising. Such introduced species must be carefully monitored to ensure that they do not evolve into invasive weeds. Although not a commercial species, silverberry may be able to stabilize the soil, adding organic matter, providing wind protection, and creating an environment suitable for establishing forest cover. Recent advances in biotechnology may provide native species that can be genetically engineered for increased salt tolerance. Introduced species, such as pitch pine (*Pinus rigida),* a native species of northeastern North America, may also prove useful in the restoration of salinated areas. It is also one of the few conifers that can resist damage from grazing because of its coppicing ability.

Afforestation of such areas is essential to restore soil fertility and reverse the salination process that results from excessive evapo-transpiration following irrigation, soil fertilization, or intensive agricultural practices. Afforestation must begin with the establishment of a vegetative (herbaceous) cover that stabilizes the soil before trees can be established. Otherwise, leaf or needle abrasion from windblown sand or snow is likely to destroy tree foliage. Identifying and testing species adapted to such harsh environments will be a key strategy in restoring these sites. In the interests of reversing such ecological degradation, a good case can be made for the introduction and testing of exotic species such as silverberry, or the introduction of plants genetically transformed, either through selective breeding or biotechnology, for increasing salt tolerance.

Riparian Systems

Removal of trees and forests next to watercourses often results in degradation of water quality and fish habitat. Water quality is possibly the foremost environmental and human health issue worldwide, including in northern China. Water protection must be an integral part of forest restoration activities and reforestation of streams and riverbanks should be a forest management priority. Forests have a vital and widely recognized role in water conservation and watershed management. Preserving buffer strips of trees and forests along streams and river edges can minimize siltation and pollution, maintain water temperatures for fish and amphibian populations, and provide forage and cover for domestic animals and wildlife.

Opposition may be met in agricultural areas where maximizing crop production is a priority. However, planting trees may provide some direct economic benefits to agriculture through improvements in water quality and habitat for the fish and frogs that supplement human diets. Forested strips along watercourses can also provide valuable habitat for native and domestic birds. These benefits need to be better understood and evaluated. Riparian zone management and development of policies by local governments for maintaining forest cover around streams could be one of the most important issues for forest and land management in northern China, and in many other areas around the world.

China is rich in native willow species and is a worldwide center of diversity for this genus. The potential for exploitation of this native resource, both for ecological and economic benefits, appears to be poorly understood. These shrubby species can be found in many low-lying wet areas where they serve a vital ecological function in streambank stabilization and protection of water quality. Willows also represent a largely unexploited biomass and fiber resource (Mosseler *et al.* 1988) that may become very important in minimizing fossil fuel dependence and utilizing renewable biomass as raw materials for chemical production.

Willows can be used as fuel wood or as an alternative fodder for livestock such as sheep and cattle. We recommend that more attention be given to native willow species as a resource for watershed management, habitat improvement, and as a fast-growing source of biomass. The characterization of native willow species provides a major new avenue for forest research and commercial exploitation in China.

Maintaining Local Population Sizes to Enhance Population Viability

In tree species that propagate through outcrossing, including most of the native trees of Jilin, maintaining local populations of at least several hundred reproductively mature individuals of each species at densities of at least 10-20 trees/hectare is necessary to maintain good quality seed production, to ensure natural regeneration, and to maintain population viability. Keeping population sizes above certain thresholds is important for maintaining genetic diversity, reproductive success, and to avoid inbreeding depression. This is especially important in the case of rare species and for tree species that people depend upon for good quality and quantities of seed. Edible pine nuts from the Korean pine (*Pinus koraiensis*), gathered in many locations in the Changbai Mountains, is one important regional example where small, isolated patches of pine trees are used to gather seed nuts. Many of these patches appear too small to produce good quantities of seed because there is insufficient pollen for the successful fertilization that is normally required to produce filled seeds. Population size needs to be maintained above certain thresholds for adequate pollination and for proper seed development and seed nut production.

In Canada, a similar and closely related five-needled pine, the eastern *Pinus strobu)*, has been artificially hybridized with Korean pine, to introduce resistance to a disease that affects native white pine. Through experimentation, we have found that quantities of viable seed production are related to stand size and density of mature stems within stands. Seed yields are reduced in small, isolated, low-density tree stands due to the deleterious effects of inbreeding within small populations (Rajora *et al.* 2002; Mosseler *et al.* 2003). The critical threshold of population size is difficult to determine with certainty because it is a function, and combination, of both absolute population numbers and the spatial distribution of tree stems (e.g., density per hectare) where interbreeding is expected to occur. Several thousand trees within a relatively contiguous area may require only 5-10 trees per hectare to sustain good seed production. If there are only 100 trees in an area, then stem densities of between 10-20 mature trees per hectare may be required for good seed production.

Introduction of Foreign Woody Species

The potential benefits from the introduction of foreign tree species are of great interest to the forest sector in Jilin. China and Canada share similar climatic and other environmental conditions, suggesting that Canadian species may do well in parts of China. However, the Changbai Mountains are rich in native, locally adapted tree species. It is reasonable to assume that tree species from Canada, or elsewhere, would not provide benefits that could not be provided by native, locally adapted species. On some occasions and under specific circumstances, a foreign species may provide benefits. Perhaps the most commonly cited example would be the introduction of *Pinus radiata* from its native California into New Zealand. However, such examples are quite rare. More often, introduced species are either poorly adapted or have brought with them introduced pests that may attack native species. North America has experienced several devastating examples of pest introductions that have had disastrous consequences for native forest diversity.

For example, in China, introduced pines (e.g., *Pinus nigra)* appear to be particularly vulnerable to attack by bark beetles such as *Tomicus piniperda.* These bark beetles are opportunistic pests that tend to attack weakened or stressed trees. Therefore, their presence on a tree is often an indicator of stress or maladaptation. Insect pests such as bark beetles provide potentially useful indicators of tree and forest health, and their activity provides an opportunity to monitor forest health and the results of using exotic tree species. It is generally safer to use well-adapted native species and it is recommended that forest managers focus on the use of native woody species wherever possible for forest restoration and timber production.

Tree Improvement

An alternative to the use of exotic species should be a comprehensive tree improvement program with native species. Although human activities have affected the population structure of many tree species, forest trees are still essentially wild populations. As such, most of the tree species contain a large amount of natural genetic variability, which will make genetic improvement effective. Conventional forest tree improvement involves four major activities: (1) assessment of genetic variability; (2) selection of superior trees; (3) establishment of seed orchards; and (4) genetic testing. Genetic tests provide data for quantifying genetic gain for various traits, and for identifying superior genotypes for next generation improvement.

The genetic improvement of native tree species requires a long-term investment in establishment and maintenance of test sites, and is best conducted cooperatively by sharing the required workload among regional agencies. All the agencies involved can share the benefits of the sustained supply of genetically improved seeds for reforestation/plantation forestry. Restoration of native trees such as Korean pine, Mongolian Scots pine (*P. sylvestris* var. *mongolica*), Korean spruce (*Picea koraiensis*), Yeddo spruce (*P. jezoensis*), and Korean larch (*Larix olgensis*) could all benefit from tree improvement programs based on range-wide seed source testing and seed orchard establishment. Innovative forestry to meet current challenges requires integration of modern seedling production systems, silvicultural principles, tree improvement, and biotechnology.

Nursery Seedling Production

Several nurseries in central and eastern Jilin use bareroot tree seedling production techniques. In Canada, we have moved away from bareroot tree seedling production in favor of container-grown tree seedlings, because the latter are more efficient in the use of space, production time, labor and planting success. Container-grown seedlings are easier to handle in preparation for planting, easier to plant, and tend to have better survival after planting. Better planting success and survival may be especially important under the harsh planting conditions experienced in the poor, thin, and depleted soils of deforested areas in the Changbai Mountains.

Canadians have found that conifer root systems on bareroot seedlings are particularly vulnerable to damage and malformation during planting. These damaged root systems reduce chances for survival and often result in stunted trees and increased susceptibility to wind damage. Container systems en-

close the seedling root system within a small plug that is easier to plant in stony soils without loss or damage to the root system. Containers also help maintain a better balance between the above- and below-ground portions of the seedling, thereby minimizing drying damage under droughty or harsh conditions. We recommend that container technology be investigated for improving the results of forest restoration activities. However, we also recognize that this would involve a major and expensive change in nursery operations, requiring the construction of greenhouses and the development of knowledge related to glasshouse culture.

Use of Nurse Crops in Forest Restoration

Plantations of poplar species and hybrids (e.g., *Populus simonii* x *nigra*) are common in the grasslands of western Jilin and Inner Mongolia, where corn is grown as the major crop. Poplar windbreaks are also commonly used to protect these agricultural areas from wind erosion. Poplar plantations can provide an excellent nurse crop for the establishment of longer-lived, more permanent, and self-sustaining tree species. The protective canopy of poplars allows more shade-tolerant, or drought-susceptible tree species to thrive under the harsh conditions of these grasslands. For instance, in areas where restoration of natural forests for ecological reasons has become an important land management objective, more shade-tolerant spruces and pines, or other Angiosperms (e.g., *Acer, Quercus, Fraxinus*) could be established under these poplar plantations. This would increase the biological diversity, habitat value, and resilience of the forest to future pest and disease problems. These poplar nurse crops might also be useful for introducing and testing certain exotic species that may otherwise be difficult to establish on exposed, open areas such as the grasslands. In Canada, fast-growing, but short-lived poplar plantations are being used as nurse crops for the restoration of longer-lived, more valuable native species, such as white pine and red spruce (*Picea rubens*).

Forest Degradation and Losses of Biodiversity

Diverse and intensive human uses of the landscape in northeastern China, combined with demands for wood, have damaged habitats, biodiversity, water quality, and the productivity of natural ecosystems. Recent manifestations include the devastating floods in various parts of the country that are linked to excessive forest utilization and chronic wind erosion of soils, resulting in massive dust storms approaching continental proportions. Soil organic matter has been reduced below critical levels in areas cultivated or denuded of forests for centuries, reducing the soil's water-retaining capacity and fertility. The same processes causing such deterioration are common across the world, including areas of central and eastern Canada, which experienced serious forest and land degradation in some areas following European settlement. Long-lived, shade-tolerant, late-successional tree species are among the first species to be lost from forests that are either selectively harvested or repeatedly clearcut for timber extraction (e.g., red spruce, in eastern Canada). Conifers are particularly vulnerable because they depend on a local seed source from mature trees for natural regeneration; whereas most hardwood species are either able to coppice from cut stems, or maintain a soil seed bank of dormant seeds for regeneration. It appears likely that native conifer populations have declined in Jilin as a result of past forest exploitation. For instance, mountainsides in the Changbai Mountains that are presently dominated by *Quercus mongolica* were probably once dominated by species such as *Pinus koraiensis, Picea koraiensis*, and the native firs, *Abies* spp. These conifers grow very well in the Changbai Mountains, but are becoming increasingly rare. They are ecologically important with respect to habitat protection, maintenance of forest biodiversity, and erosion control, and have a much higher economic value for the forest industry. We recommend that every effort be made to rehabilitate declining native species, especially native conifers and associated species across their geographic ranges to improve forest habitat, biodiversity, and the basis for forest industries.

Summary

China has a rich biological diversity and is widely recognized as an important global center of biodiversity. It is important for local forest managers to recognize this treasure of native biodiversity as China's main resource for forest restoration activities. The concept that local gene pools may be expected to contain the best-adapted genotypes, until proven otherwise, is an ecologically sound assumption and one of the first principles of ecology. With few exceptions, this principle is supported by experience around the world. Although certain exotic species may deserve some research interest and testing, one should not expect exotic species to provide a "magic solution" to forest restoration opportunities. Many native species are in decline in China (e.g., *Picea, Pinus, Abies* spp. in the Changbai Mountains). These species deserve special attention in restoration efforts. Native sources of willows may also be an example of a largely unrecognized and underused native resource with huge potential for future exploitation in wetlands conservation, habitat restoration, and as a source of fast-growing biomass for fuel production and livestock forage. Current advances in biotechnology and genetic engineering of micro-organisms indicate a strong future for renewable, biomass-based energy and chemicals industries. Better use of native species would help address an emerging issue of global importance: afforestation for watershed management and the improvement of water quality for human health. We would like to recognize the good efforts of the people that are currently dealing with forest restoration under some very difficult conditions both in the deforested mountainous areas of eastern Jilin and in the salinated soils of the grasslands of western Jilin.

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References

Mosseler, A., Major, J.E., and Rajora, O.P. 2003. Old-growth red spruce forests as reservoirs of genetic diversity and reproductive fitness [J]. Theoret. Appl. Genet., **106**: 931–937.

Mosseler, A., Zsuffa, L., Stoehr, M.U., and Kenney, W.A. 1988. Variation in biomass production, moisture content, and specific gravity in some North American willows (*Salix* L.) [J]. Can. J. For. Res., 18: 1535–1540.

Rajora, O.P., Mosseler, A., and Major, J.E. 2002. Mating system and reproductive fitness traits of eastern white pine (*Pinus strobus*) in large, central versus small, isolate, marginal populations [J]. Can. J. Bot., **80**: 1–12.

Wang Xiancheng. 2001 Problems and countermeasures on restoration of forest ecological environment of Jilin Province [J]. Journal of Forestry Research **12**(2):109–114.